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UPGRADE OF BALLISTIC RANGE FACILITIES AT AEDC

BY

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For over 28 years, Arnold Engineering Development Center (AEDC) has operated the 1,000-ft-long Aeroballistic Range G, now the only major hyperballistic facility in the USA. The closure of the Delco Range, July 1, 1988, caused a review of the future plans for Range G which led to the present upgrade.

The 2.5-in. bore two-stage light-gas launcher is to be replaced by a 3.3-in. bore with peak accelerations reduced by 50 percent. This will fire into the present range tank and have a similar track and recovery capability as the present range.

In parallel to the 3.3-in. facility, a 2.5-in. bore launcher with the same capabilities as the present launcher will be used as a dedicated Impact Testing Facility. This impact launcher will be convertible to a free-piston shock tunnel capable of CFD code validation.

Upon completion of this upgrade, AEDC will possess a unique set of hypervelocity testing capabilities.

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PREFACE

For over 28 years, AEDC has operated the 1,000 ft. long Aeroballistic Range G, now the only major hyperballistic facility in the USA. The closure of the Delco Range, July 1, 1988, caused a review of the future plans for Range G which led to the present upgrade.

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In parallel to the 3.3 inch facility, a 2.5 inch bore Launcher, with the same capabilities as the present launcher, will be used as a dedicated Impact Testing Facility. This Impact Launcher will be convertible to a free-piston shock tunnel capable of CFD Code Validation.

Upon completion of this upgrade, AEDC will possess a unique set of hypervelocity testing capabilities.

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1.0 INTRODUCTION

The Arnold Engineering Development Center (AEDC) mission is to provide ground test and evaluation support to systems acquisition/development and research and development programs. AEDC customers include United States Government agencies, private industry, educational institutions, and allied foreign governments and their institutions. AEDC is sub-divided into three testing complexes: the Engine Test Facilities, the Propulsion Wind Tunnel, and the Von Karman Gas Dynamics Facilities (VKF) [see Figure 1]. The VKF comprises four high-speed wind tunnels, four ballistic and impact ranges, three arc heaters and four space chambers. The subject paper will address the AEDC on-going program to modify the large ballistic range within VKF.

AEDC has been operating the 1,000 ft. long Aeroballistic Range G for over 28 years. During this period, the range has utilized several sizes of two-stage light-gas launchers. The standard bore has been 2.5 inches (6.35 cm), although smaller two-stage launchers and larger single-stage powder guns have also been used.

The closing of the Delco Range, July 1, 1988, created an increased need for aerophysics testing at AEDC. New testing requirements also showed the need for a "softer" launcher capability and for larger models. "Soft" launch refers to minimizing the peak acceleration experienced by the model during launch. A hypersonic range study was initiated to provide solutions for these needs, which then led to the plan to upgrade the AEDC Ballistic Range Facilities.

2.0 REQUIREMENTS

The general goal was to replace and improve on the combination of the AEDC and DELCO ballistic range capabilities. This goal breaks down into the following specific requirements.

(1) Design the largest launcher with the softest launch that could be fitted into the existing Range G building.

(2) Provide as clean a range environment as possible for aerophysics testing.

(3) Minimize changes to the existing range.

The size of the G Launcher Room, its underground location and proximity to other AEDC test facilities produced the constraint of no building enlargement. Several launcher bore sizes were considered: 3.3 in., 4.0 in., and 6.0 in. during the study.

2.1 SOFTER LAUNCHER

The AEDC launcher performance code, validated by in-bore measurements in 1964 (Ref. 1), was used to determine the acceleration history for a number of pump tube, launch tube, and transition taper variables for a selected slender cone/sabot configuration. These acceleration histories were compared with those computed for the existing G 2.5 inch Launcher and the Delco Launcher. The configuration chosen, which also meets the space available constraint is shown in Figure 2. This configuration had a 100 ft. (30.5 m) long by 14.0 in. (35.6 cm) bore pump tube, a 100 ft. (30.5 m) long by 3.3 in. (8.8 cm) bore launch tube and 20° taper angle in the transition or high pressure section.

For this configuration, the design point was a package weight 2.04 lb (925 gm) and velocity of 19,000 ft/sec (5.8 km/sec). Figure 3 shows the comparison of the acceleration histories of this 3.3 inch Launcher, the Delco 2.5 inch Launcher and the AEDC 2.5 inch Launcher.

It is clear that the 3.3 inch Launcher peak acceleration of 78,000 g's is much lower than that of the Delco Launcher (125,000 g's), and G (186,000 g's). The major difference between the two 2.5 inch Launchers is the pump

tube diameter. The Delco launcher has a 10 inch bore compared with AEDC's 8 inch. This is the major reason for Delco's softer launch capability.

2.2 CLEAN RANGE

A major contributor to making a range dirty is impact testing. At AEDC it has required up to two weeks of cleaning of the range to change from an impact to an aerophysics test. Paralleled to the G Launcher, there used to be an electromagnetic shock tube. This had been salvaged a number of years ago, but a large vacuum tank, 8 ft. diameter by 80 ft. long, still remained. This tank has a full 8 ft. diameter door at the far end making it very suitable for handling large targets, which were difficult to install through the G Range, 5 ft. by 2.5 ft. doors. The tank is long enough to provide a blast tank for sabot stripping and a target tank. There is also sufficient space to install the AEDC 2.5 inch Launcher in the Launch Room firing into this tank. It was decided to remove impact testing from the 1,000 ft. long Range G and set up a dedicated Impact Facility using 2.5 inch launcher parts and this vacuum tank.

2.3 MINIMIZING CHANGES

Referring to Figure 3, it can be seen that peak acceleration for the 3.3 inch Launcher occurs 55 ft. from start of projectile motion. The acceleration after 100 ft. of travel is a little higher than that at the muzzle of the G Launch Tube at 68 ft. and the Delco at 75 ft. To accommodate this increased length, it is necessary to move the blast tank further from the launcher, since the underground siting of the range and the proximity to other test facilities preclude moving the launcher away from the range tank.

An artists concept of these two launchers is shown as Figure 4. Another group at AEDC had been looking for a wind tunnel capable of reproducing real gas effects, and thus, being used for Computational Fluid Dynamics (CFD) code

validation. They were considering a free-piston shock tunnel. The idea was conceived of using a two-stage light-gas gun as driver for this shock tunnel. After discussions, it was determined that the 2.5 inch Impact Launcher could be used as the driver for the shock tube. So, on Figure 4, the Impulse Tunnel is shown as an alternate to the Impact Launcher. To change over from the impact launcher, the 68 ft. launch tube is removed and replaced by a 40 ft. long, 3 inch bore shock tube coupled to a hypersonic nozzle and wind tunnel test section (Figure 5).

These three test facilities will now be described in more detail.

3.0 THE 3.3 INCH BORE LAUNCHER

As described above, this launcher will have a 3.3 inch bore by 100 ft. long launch tube, a 14 inch x 100 ft. long pump tube and a 20 inch bore by 12 ft. long powder chamber. To accommodate this length of launcher, 71 ft. will be cut from the 10 ft. diameter range tank and the blast tank moved and rewelded to the range tank. The 2.5 inch launcher has 39 ft. of launch tube inside the blast tank due to increases in the length of the launch tube incorporated since its original installation in 1963. To maximize sabot stripping distance, the new 3.3 inch Launcher Tube will only have 2 ft. of launch tube inside the blast tank. All launch tube supports will rest on a solid concrete floor. The present 2.5 inch launcher has six supports mounted on the wall of the blast tank, whose flexibility causes launch tube alignment difficulties. In order to preserve the existing 30 inch diameter Schlieren Station, the blast tank will be shortened by 6 ft. Range G has the unique track and recovery capability for its 2.5 inch launcher (Ref. 2). To maintain this capability, a 3.3 inch track and recovery tube system will be installed. Since the launch accelerations are reduced by this new launcher, a 200 ft. longer recovery tube will be used to reduce the deceleration loads

required to recover models. All the existing instrumentation capability will be preserved except for three orthogonal visible light shadowgraph stations which will be removed from the shortened range tank. Forty-nine stations will remain, preserving the aerodynamic measurement capability. As well as the instrumentation modifi-cations, all the electrical, hydraulic, and gas filling systems, will be modified.

The predicted performance capability of this larger launcher is shown as Figure 6. The velocity capability is the same as the 2.5 inch launcher. The major improvement is that the package weight which can be launched at a given velocity, is approximately doubled. This will allow testing of long, slender models as illustrated in Figure 7 and also the launch of models with on-board instrumentation packages.

4.0 THE IMPACT FACILITY

The Impact Facility will have the same performance as the existing 2.5 inch bore launcher (Figure 6). It is planned to install this launcher using existing spare components while the present 2.5 inch bore launcher is operational. This launcher will be installed on the east side of the launch room (Figure 4). The existing vacuum tank will be moved 22 ft. north to accommodate this installation and to maximize the sabot stripping distance. The launcher installation is shown in Figure 8. The launch tube mounting system can accommodate air bearings to simplify removal during the change-over to the Impulse Tunnel. The existing vacuum tank will be modified by incorporating a bulkhead to separate the blast and target tanks (Figure 9). Supports will be provided in the blast tank to allow use of the 2.5 inch track when needed. Quick-operating valves will be used to separate the pressures and gases in the blast ank range tanks. Large 6' x 1' windows will be installed to view the target area orthogonally. Angled ports will be

provided to allow near head-on viewing of the impact on the target. All existing instrumentation now used for impact testing can be used with this new facility including the high-speed cameras, radiometers and spectrographs.

5.0 THE IMPULSE FACILITY

This short duration (~ 1 millisecond) wind tunnel utilizes the powder chamber, pump tube and high pressure section of the 2.5 inch bore impact launcher as the driver for a free-piston shock tunnel (Figure 5). The launch tube will be replaced by a 3.0 inch bore shock tube coupled to a 8° semi-angle nozzle with an exit diameter of 18 inches and a free-jet test section 42 inches in diameter. The test section will be coupled to an extension tube connected to the impact facility blast tank. Models will be mounted on a support strut adjustable for angle of attack. The main data measurements will be flow field visualization, pressure and temperature. Interchangeable throats will be used to change the Mach Number. The gun-powder driven piston will compress helium which will drive a shock wave into the air in the shock tube which will provide the test gas for the test section. The shock wave will reflect from the nozzle face to provide a longer period of "constant" reservoir pressure and length in the test run time. It is planned that the reservoir pressure to reach 10,000 atm at maximum capability utilizing the launcher's extruding pistons. Existing free-piston shock tunnels are restricted to 2,000 atmospheres and use reusable pistons. The enhanced capability of the AEDC Impulse Facility will provide a unique capability for CFD code validation at hypervelocities.

6.0 STATUS OF THE UPGRADE

The design of these three facilities was completed in FY91. Funding was provided in FY90 and 91 to contract for the long lead time items for the 3.3 inch launcher, i.e. the powder chamber, pump tube, high pressure section and

launch tube. Funding in FY92 will complete procurement and fabrication of the impact and impulse components and a major portion of their installation. Procurement for the 3.3 inch Launcher will also be completed in FY92. A major portion of the fabrication of the 3.3 inch components will also be completed in FY92. Checkout and validation of the Impact/Impulse Facilities is planned for early FY93. When these facilities are operational, the 1,000 ft. Range will be shut down for installation of the 3.3 inch Launcher and relocation of the blast tank. Checkout and validation of this facility is planned for the end of FY93.

7.0 SUMMARY

Upon completion of this upgrade, AEDC will have a unique set of hypervelocity facilities, with superior capabilities in soft-launch for long, slender models, recovery for models with on-board instrumentation, and for CFD code validation.

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2. Cable, A. J., "The Hypervelocity Range Track Facilities at AEDC," 28th Aeroballistic Range Association Meeting, Eglin AFB, Florida, September 28-29, 1977.

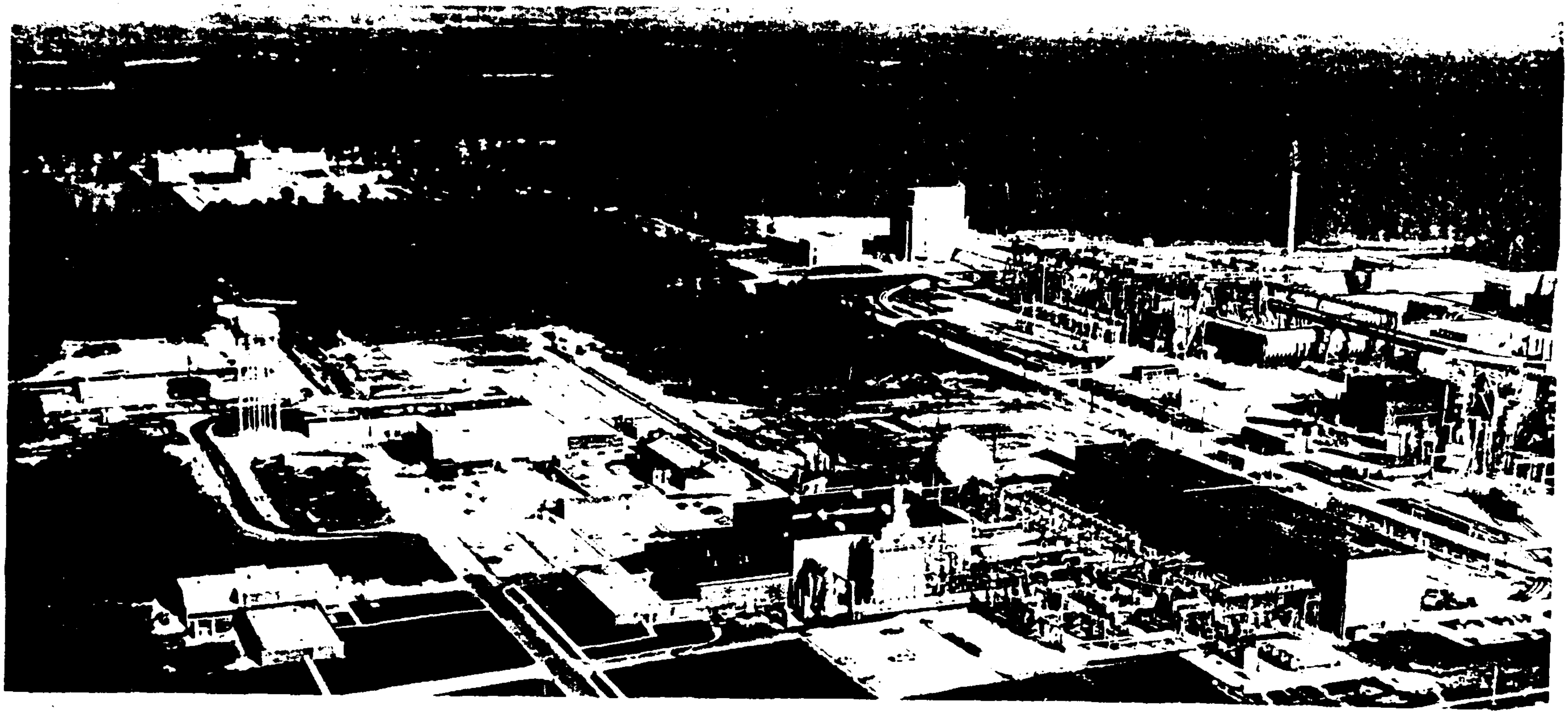

FIGURE 1 ARNOLD ENGINEERING DEVELOPMENT CENTER
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AFB, TENNESSEE 37389

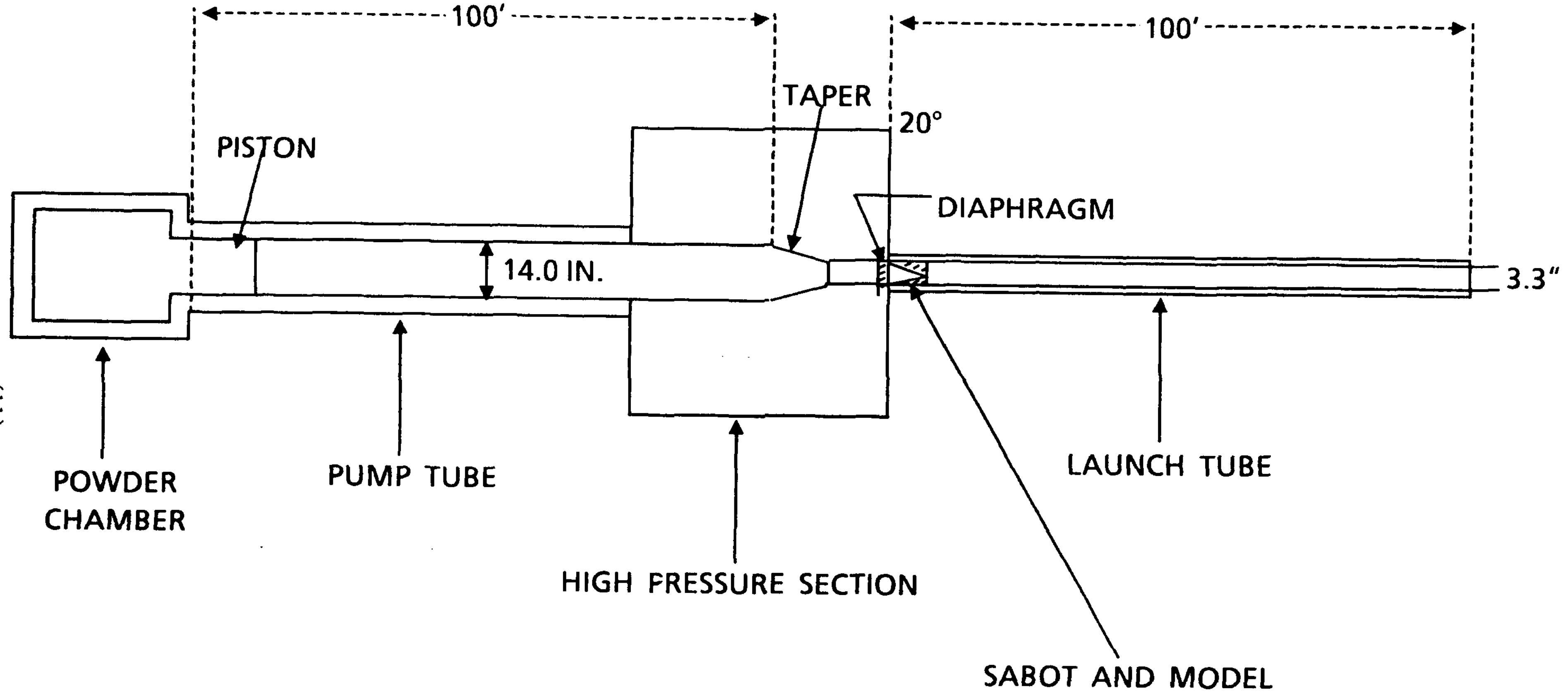

FIGURE 2 3.3 INCH LAUNCHER CONFIGURATION

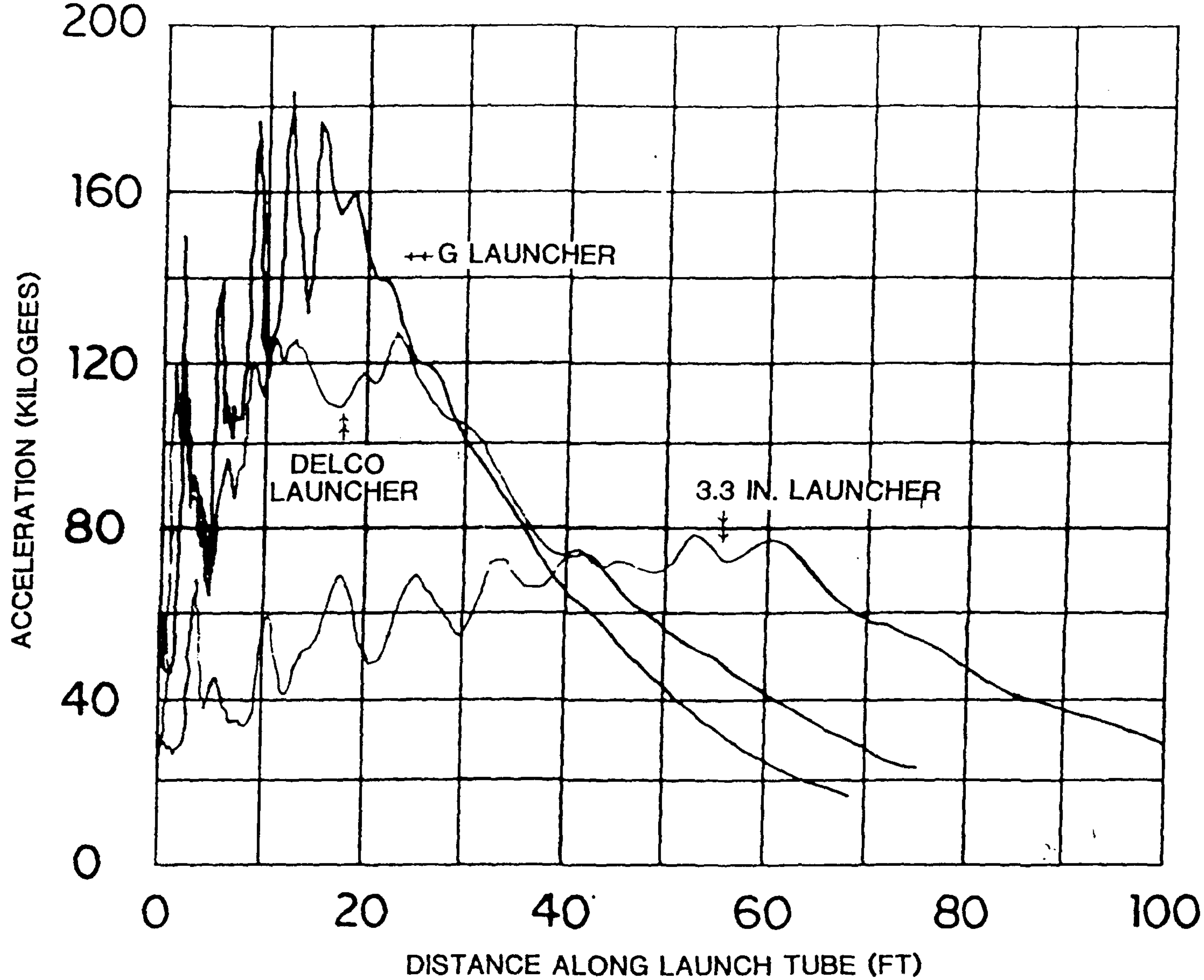

FIGURE 3 COMPARISON OF G, DELCO, AND PROPOSED 3.3 INCH LAUNCHER ACCELERATION HISTORIES

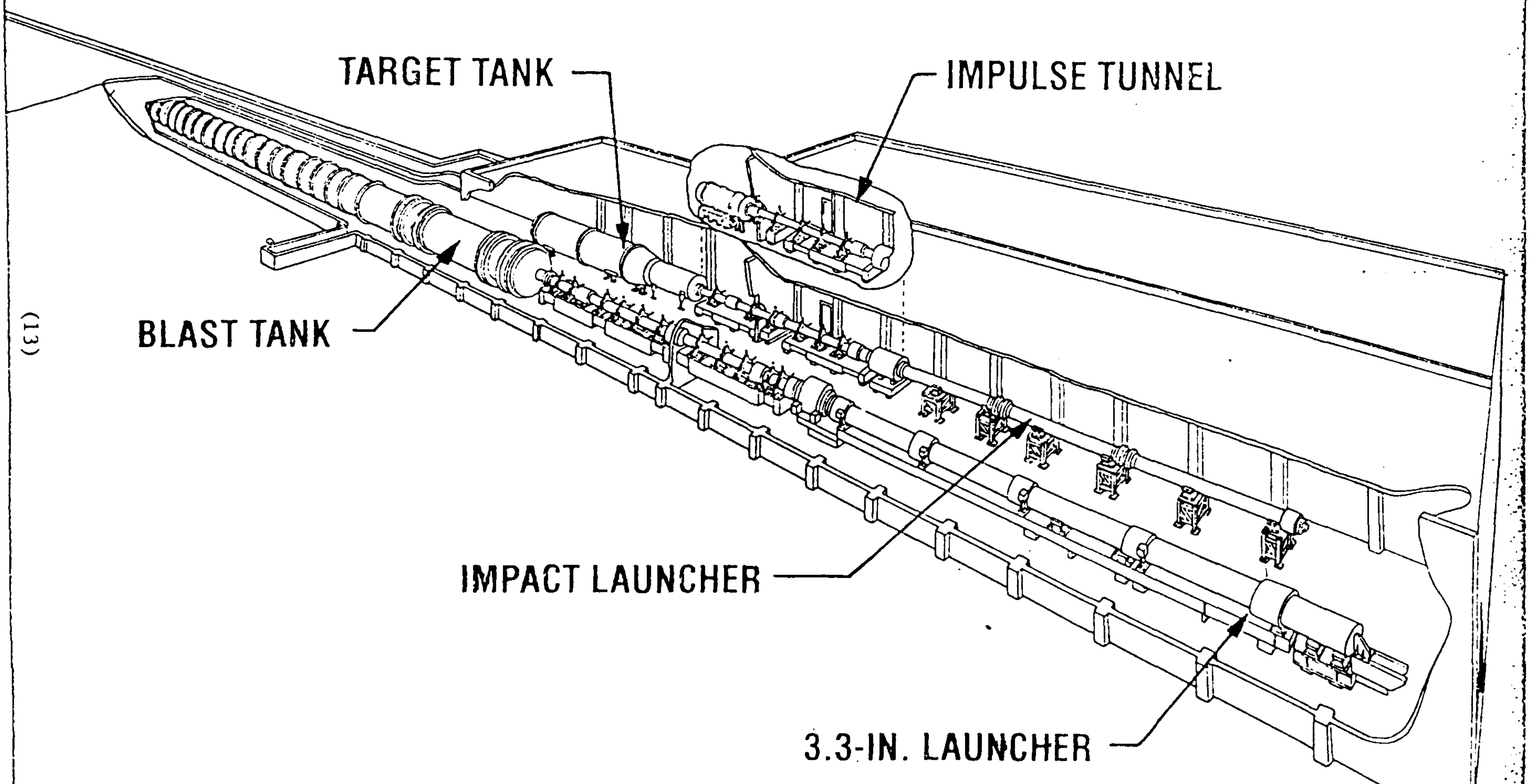

FIGURE 4 THE UPGRADED BALLISTIC RANGE CAPABILITY

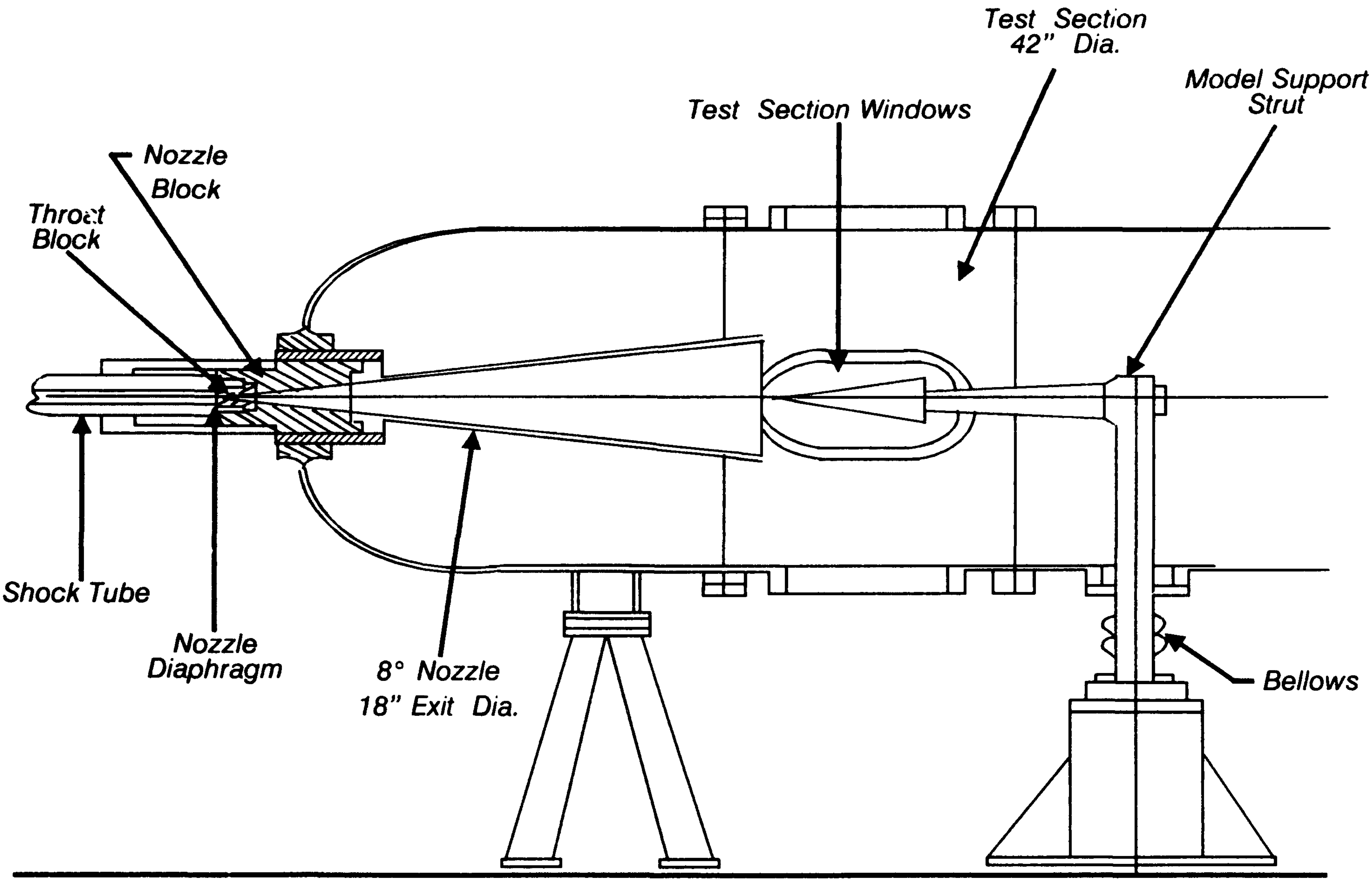

FIGURE 5 THE IMPULSE TUNNEL

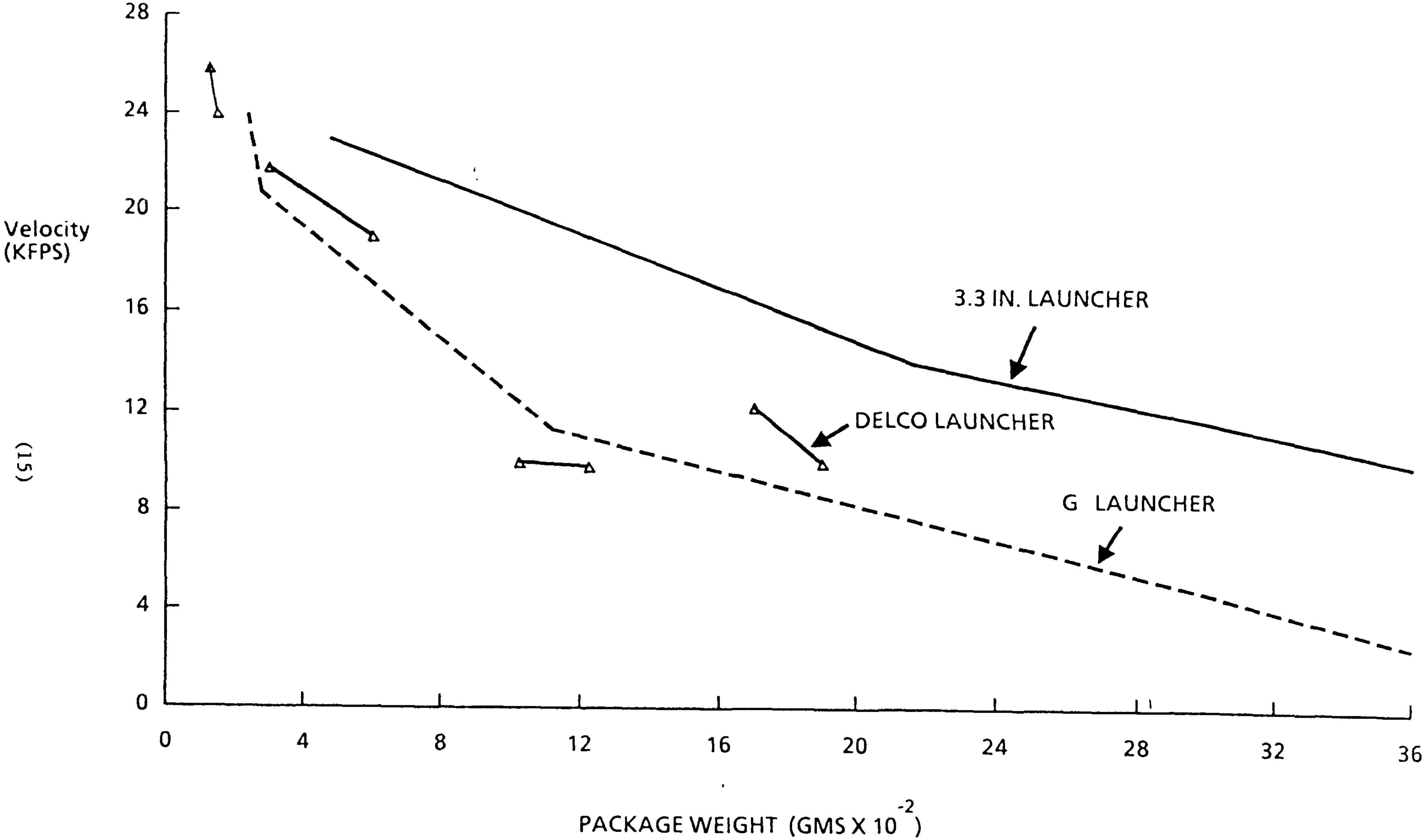

FIGURE 6 PREDICTED PERFORMANCE OF 3.3 INCH BORE LAUNCHER

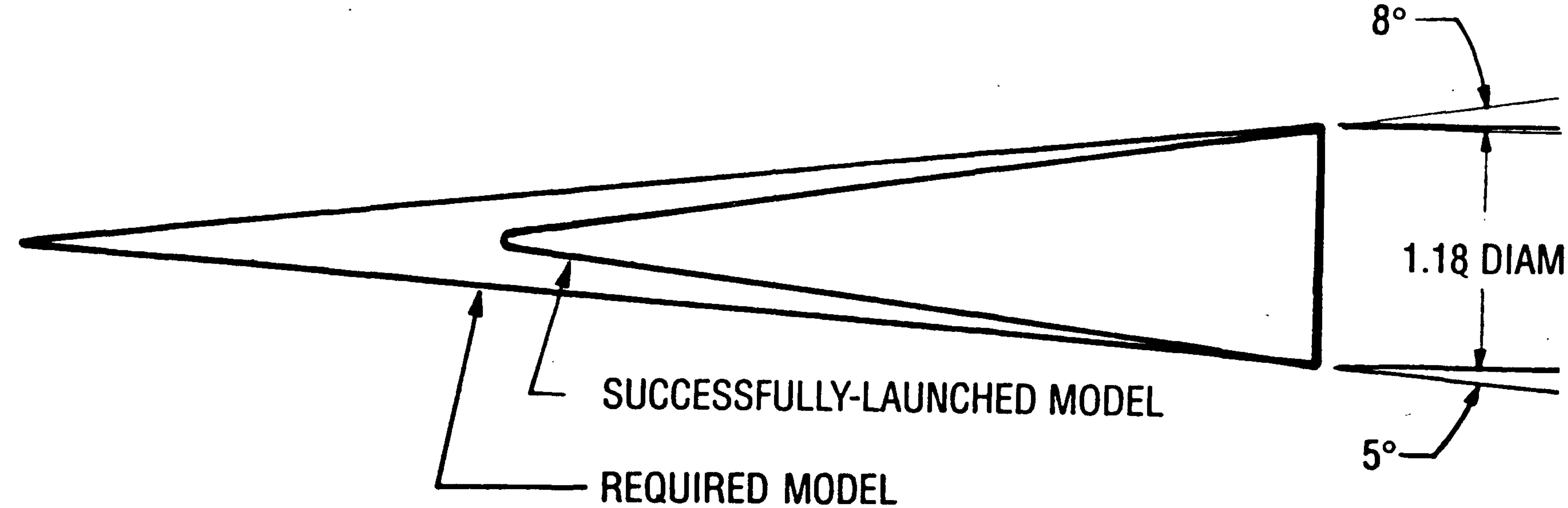

FIGURE 7 EXAMPLE OF IMPROVEMENT IN MODEL LAUNCHING CAPABILITY

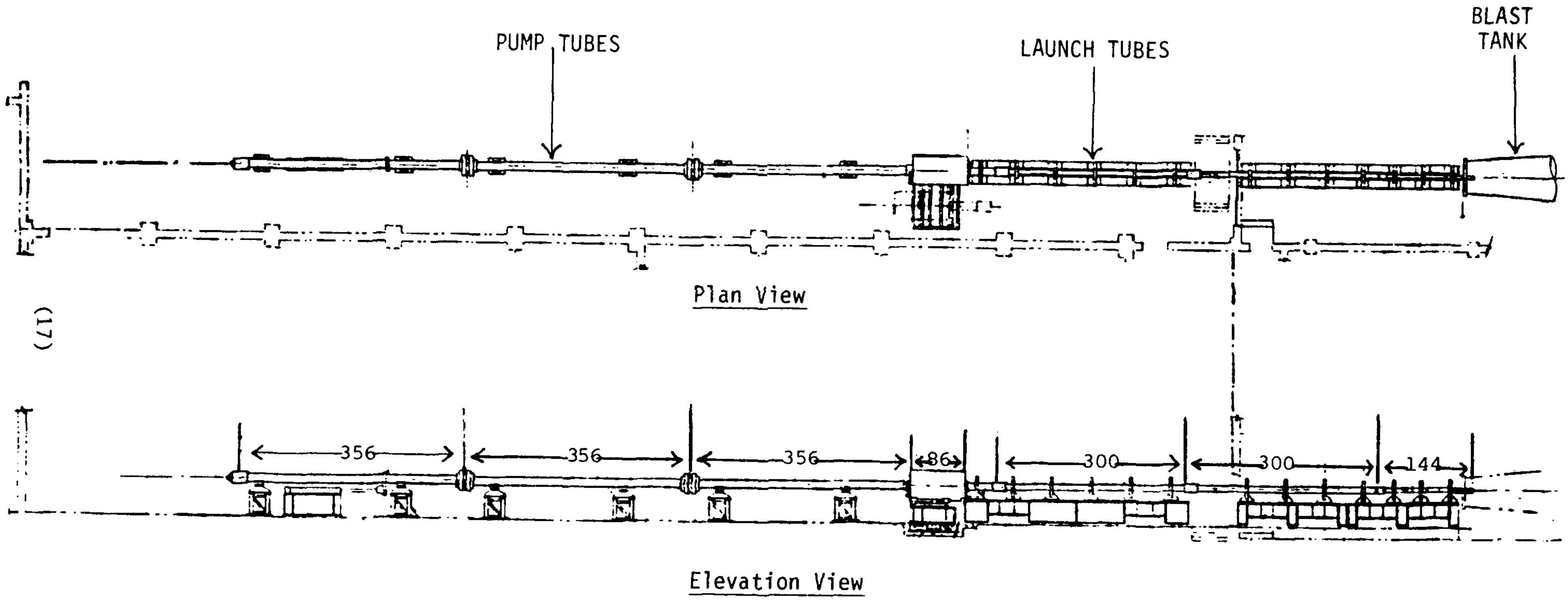

FIGURE 8 THE IMPACT LAUNCHER

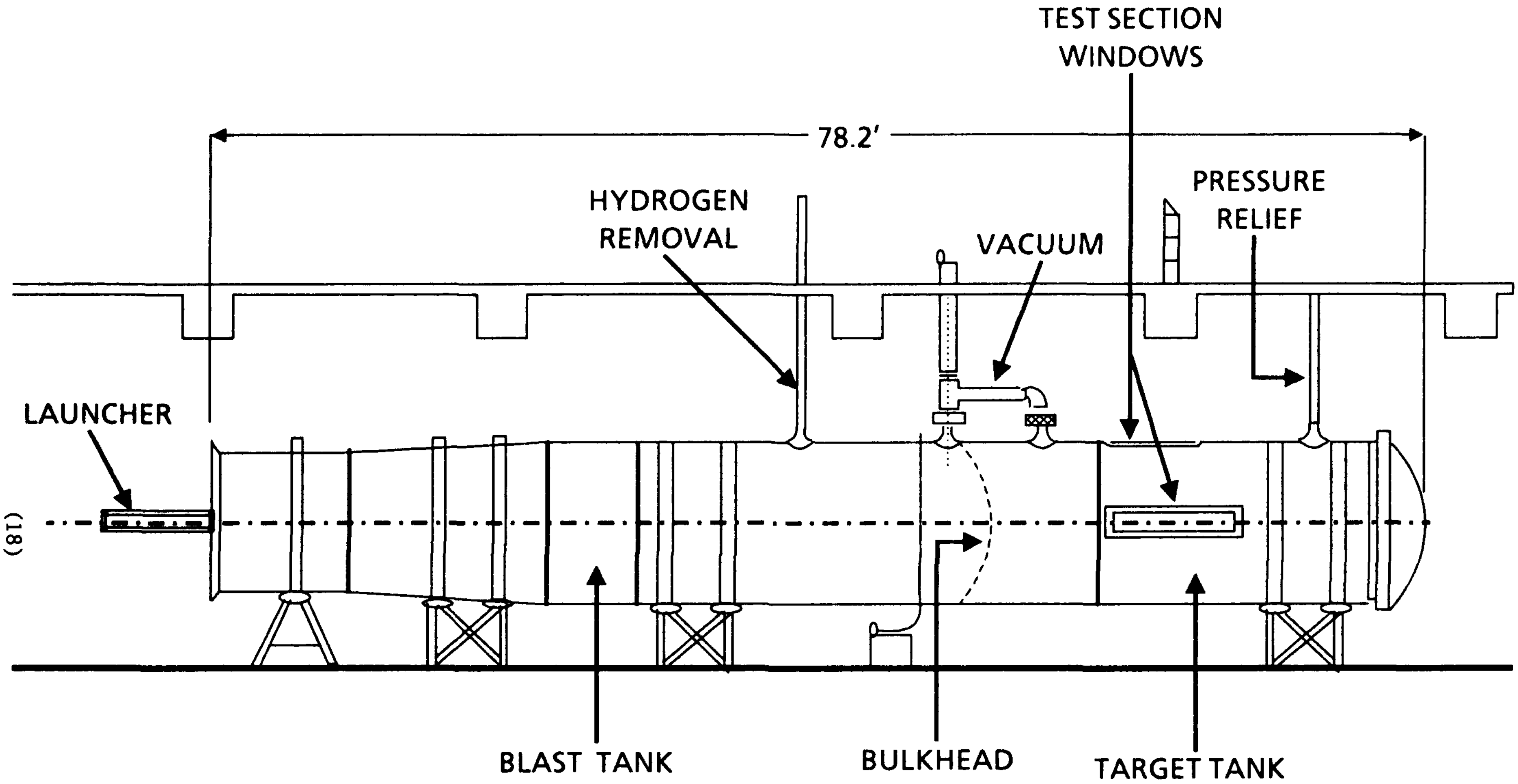

FIGURE 9 THE IMPACT BLAST & TARGET TANK